INFORMATION AND CONTROL FOR RESOURCE

MANAGEMENT IN A GROWING MARKET

Carl V. Swanson

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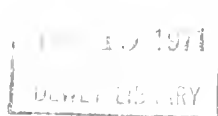
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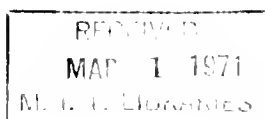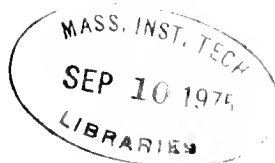MANAGEMENT IN A GROWING MARKET

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INTRODUCTION

Time and again, hindsight shows that by expanding its resources slowly, a firm has failed to exploit a rapidly growing market. Yet when making the resource decisions, managment believed that demand did not justify faster expansion. The first part of the paper explains this paradox. It shows how a typical resource control policy can retard growth while persuading management that demand is growing more slowly than it really is. The second part of the paper recommends an improved resource control policy. The third part of the paper shows that when properly implemented the recommended policy is not risky. It has less risk of failing to exploit demand than the typical policy. It also has low risk of excess resources. Finally, implementation of the re- commended policy is discussed.

Industrial Dynamics[2] and computer simulation[8] form the analytic base of this paper.

A TYPICAL POLICY

In a growing market, management tries to match resources with demand. Unfortunately, demand cannot be measured. It can only be estimated from other variables. Typically, management estimates demand from the order rate, unfilled order backlog, and inventory. This information flow couples the market and resources in a feedback structure which causes the paradox of slow growth while management apparently matches resources to demand.

The key to understanding the paradox is the feedback relationship coupling resources, competitive variables, order rate, demand, and order load as shown in Figure 1. This is a fundamental relationship existing between the resources of every firm and its market. This feedback relationship limits the order rate to the capacity of resources, or, if resources are ample, to demand. This relationship is a non-linear, negative feedback control of the order rate by resources.

The control of the order rate by resources operates in the following manner. With any resource is associated a competitive variable such as customer service, product line, advertising lineage, or delivery time. Resources are intended to maintain or improve competitive variables. For example, additions of production resources reduce delivery delay. Increased promotion adds to product awareness. Research and development improves old and creates new products. If the order rate outstrips the capacity of resources, the order load builds up and the competitive variable deteriorates. For example, an order rate greater than produc-
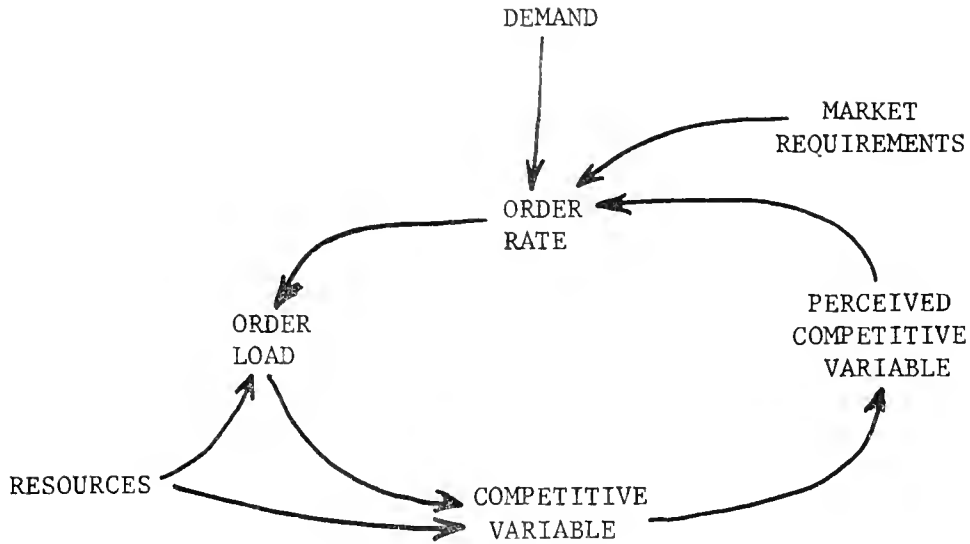
FIGURE 1. Fundamental Relationship between Resources and the Market.

tion rate reduces inventory or increases backlog which lengthens the

delivery delay. Or in another case, a product line becomes obsolete

as increased orders keep the product development department filling

special customer needs and solving production problems. Finally, the

ordering of airline tickets, getting a loan, or asking a stockbroker to

make a transaction is made difficult as heavy business ties up phone

lines, loan officers, or salesmen. After the length of time it takes

customers to perceive the deterioration of the competitive variable,

some customers discover that their needs are not being met or that a

competitor's performance is better; so they purchase from other suppliers

or do without. As the competitive variable continues to deteriorate, the order rate becomes a smaller fraction of demand. (In this paper, demand is defined as the order rate that prevails when the competitive variable has a normal value.)

A Typical Resource Control Policy

Computer simulation is used to show how a typical resource control policy can slow growth while management believes resources are meeting demand. First the typical policy is described and then the dynamic behavior generated by the computer simulation is analyzed.

In the computer simulation model, the resource is production capacity, the order load is backlog, and the competitive variable is delivery delay. In the typical resource control policy demand is estimated from order rate and backlog.

The resource control policy is shown in Equation (1) and in Figure 2.

$$\begin{matrix} \text{DESIRED} \\ \text{SHIPMENT} \\ \text{RATE} \end{matrix} = \begin{matrix} \text{AVERAGE} \\ \text{ORDER} \\ \text{RATE} \end{matrix} + \left(\frac{\text{BACKLOG} - \text{DESIRED BACKLOG}}{\text{5 MONTHS}} \right) \qquad (1)$$

A desired shipment rate is set equal to the average order rate plus the amount needed to bring backlog to its desired value (one month of average sales rate) within five months. As shown in Figure 2, the typical policy wants desired production capacity to be 10% greater than the desired ship-
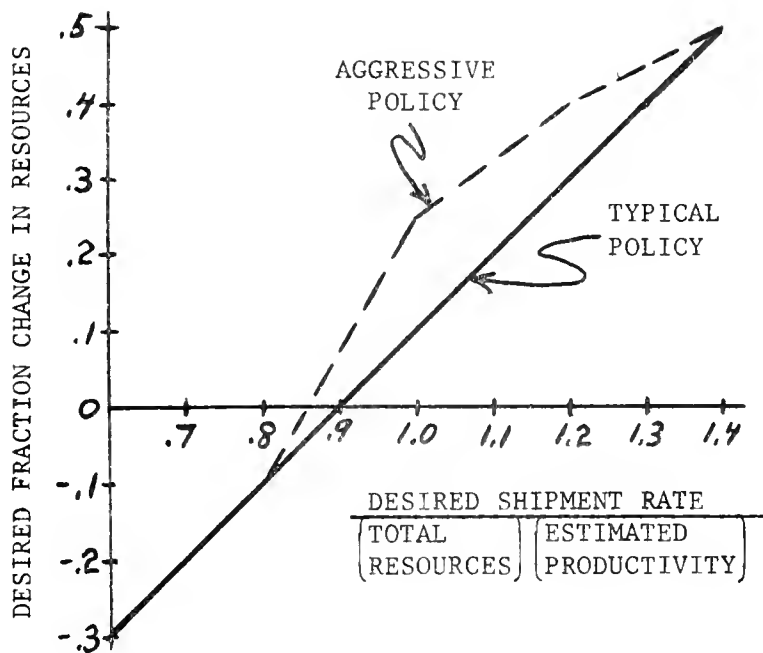
FIGURE 2.   Graph of Desired Fraction Change in
Resources in Resource Control Policy

ment rate. This is not a particularly conservative policy. The com-
bination of backlog adjustment and the desired 10% overcapacity means
that desired resources are 32% greater than the order rate when the
backlog is two months of orders. The policy will increase capacity as
much as 50%, if the order rate and backlog justify it. The first simu-
lation run assumes an average of twelve months to acquire, install, and
make productive additional capacity. The additions to production rate
are distributed over time. Six months after additional capacity is
ordered 8% is productive, after twelve months 50%, and after twenty-
four months 95% of the capacity ordered is fully productive.

An industrial product was the example for establishing the effect of delivery delay and the competitive variable upon the order rate. It is assumed that a one-month delivery delay is normal and at that value the order rate equals demand. The order rate is 10% greater than normal demand when orders are filled immediately. When delivery delay is two months, the order rate is 70% of demand, at three months 40%, and when delivery delay is four months the order rate is 5% of normal demand.

Behavior of the Typical Policy

Figure 3 shows that the typical policy just described retards growth when demand grows 10 times in ten years during which the maximum annual growth is 67%. At twenty-four months (two years) the order rate is 65% of demand; at forty-eight months (four years) the order rate is 44% of demand; at seventy-two months (six years) the order rate is 53% of demand. Not until one hundred and twenty months (ten years) is the order rate approximately equal to demand.

Let us examine the simulation output (Figure 3) more closely in order to understand how growth is retarded. Initially, resources are 11% greater than demand. Backlog is one month of orders, its desired value, which means that delivery delay is one month. A one-month delivery delay meets market requirements, so the order rate equals demand. In the first year, demand grows 50%, resources are ordered but due to the twelve-month delay in the acquisition of resources, the order rate begins to exceed production capacity, the backlog and delivery delay in-
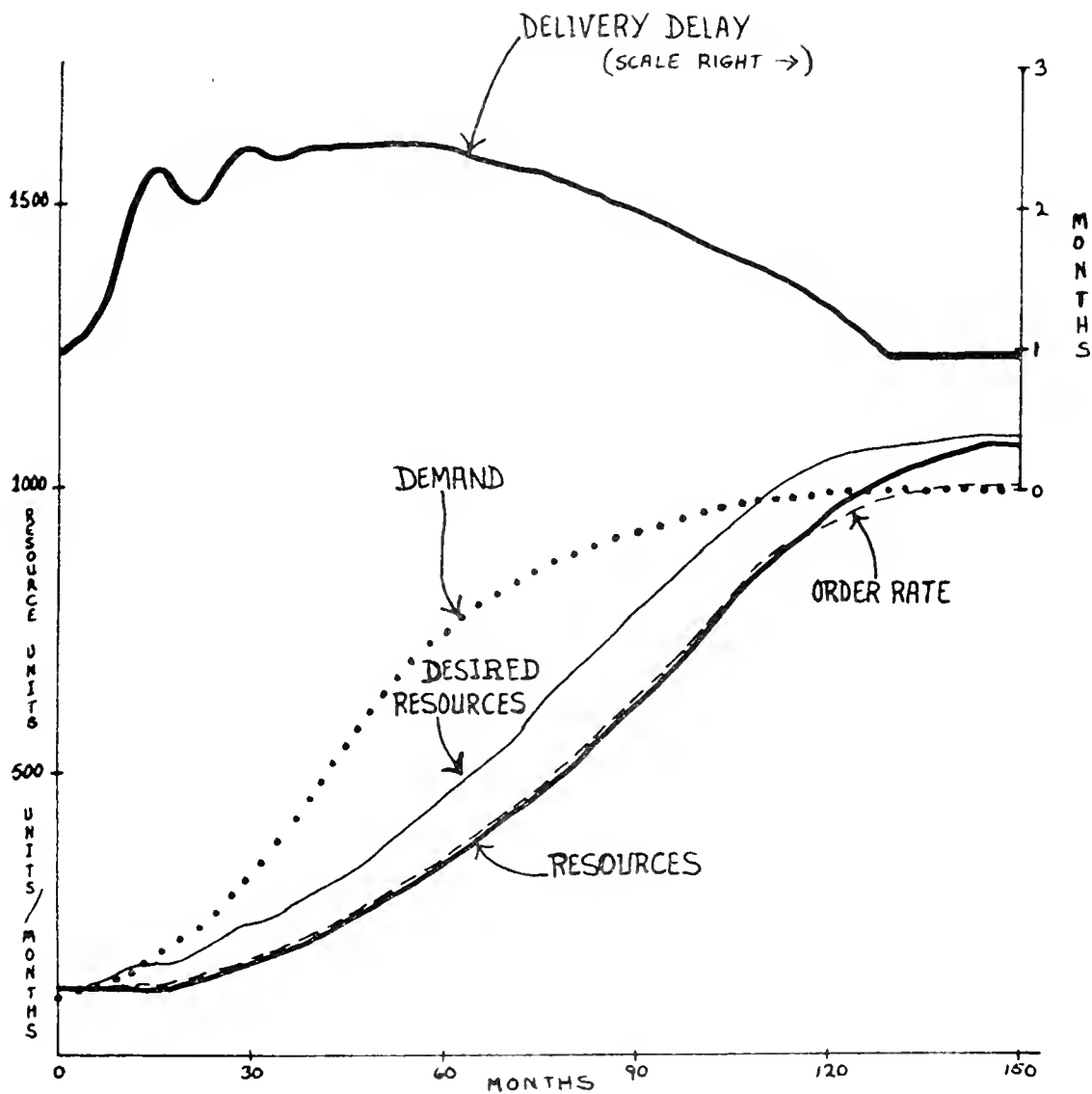
FIGURE 3. Retarded Growth Due to Typical Resource Control Policy

crease. By Month 12 the delivery delay is two months causing the order
rate to be 70% of demand and nearly equal to production capacity. With
order rate nearly equal to production rate, backlog ceases to grow.
The feedback loop linking resources and the market (Figure 1) has made
a mockery of the estimate of demand from order rate and backlog. The
order rate is controlled by production capacity and the backlog cannot
grow large. What the unwary call an estimate of demand is a better
estimate of the firm's own production capacity.

By examining the resource control policy in detail, we gain addi-
tional understanding of the slow growth. The feedback loop linking re-
sources and the market limits backlog to about two months of orders
and it keeps the order rate about equal to production capacity. With
backlog limited to two months of orders, which is twice the desired
value, the desired shipment rate, Equation (1), is 20% greater than the
order rate. The policy of striving for resources 10% greater than the
desired shipment rate, Figure 2, puts desired resources 32% greater
than the order rate. But since the order rate is controlled by pro-
ductive capacity, desired resources are 32% greater than current pro-
ductive capacity. Since it takes twelve months on average to acquire
the desired resources, resources will grow at a maximum rate of about
32% per year. Since demand grows faster, up to 67% a year, resources
lag behind and retard the growth of the firm.

Ironically, while the typical policy retards growth, management
is willing to expand much more rapidly. However, the interaction be-

tween the firm and the market presents ample evidence that demand is almost fully exploited.

1. The order rate exceeds the rate of shipments by very little. There is no dramatic spurt in the order rate which would indicate unfilled demand.

2. The backlog, while it is high, never reaches extremely large values. After a while the high and stable backlog may be taken as normal, which will only reduce growth and diminish any belief that demand is unfilled.

3. Regular customers tell the firm that a two-month delivery delay, which is holding down the order rate, is either livable or satisfactory. Those customers who insist upon fast delivery either purchase elsewhere or do without. The firm has no direct and immediate contact with customers demanding faster delivery.

The same feedback structure in Figure 1 and these typical resource control policies can produce other more insidious modes of behavior in a growing market. They can produce corporate stagnation and give the illusion of a stagnant market ([12] pp. 61-65). They can also generate apparent seasonal demand where none exists in the market and slow growth ([13] pp. 67-77 and [14]). Research by others confirms that the information structure and resource policies of the firm retard growth and/or produce fluctuations [3,4,5,7,16].

The important question then is how to design information flows and resource control to improve the exploitation of demand.

Two ways are: 1) to expand resources more aggressively by following a resource control policy represented by the dashed line in Figure 2 and 2) to reduce the time to acquire and assimilate resources (see[13] pp. 78-88). Being more aggressive and reducing resource acquisition delays does improve the exploitation of demand. But relying upon fine tuning of decision parameters (making control more aggressive) or hoping for a favorable environment (short resource acquisition delays) is poor policy design practice because the resulting design is still unable to cope well with some markets. A well-designed information flow and resource control policy produce good behavior for a wide range of different market characteristics and resource supply conditions. Some may think that forecasting demand by extrapolating the order rate will improve the performance of this typical resource control policy, but as has been shown[4], extrapolation forecasting does not overcome the retardation of growth.

THE RECOMMENDED POLICY

A much better approach to policy design is to identify, measure, and base control actions upon variables which reveal how well current resources are exploiting the market. Since the only way order rate is kept below demand is if a competitive variable (delivery delay in Figure 3) fails to meet market needs, a good indicator of the exploitation of demand is the value of a competitive variable.

One way to incorporate the competitive variables into resource management is to estimate demand from current information of the competitive variables using an estimate of how the competitive variables affect demand. This estimate of demand is based upon the assumption that:

$$\text{ORDER RATE} = \left(\text{DEMAND}\right)\left(\begin{array}{l}\text{FRACTION OF DEMAND REALIZED}\\\text{DUE TO COMPETITIVE VARIABLE}\end{array}\right)$$

Demand then can be estimated as:

$$\text{ESTIMATED DEMAND} = \frac{\text{AVERAGE ORDER RATE}}{\begin{array}{l}\text{ESTIMATED FRACTION OF}\\\text{DEMAND REALIZED DUE TO}\\\text{THE COMPETITIVE VARIABLE}\end{array}}$$

This estimate of demand is substituted for average order rate in the desired shipment rate of Equation (1) to produce a new resource control policy.

$$\begin{array}{l}\text{DESIRED}\\\text{SHIPMENT}\\\text{RATE}\end{array} = \frac{\text{AVERAGE ORDER RATE}}{\begin{array}{l}\text{ESTIMATED FRACTION OF}\\\text{DEMAND REALIZED DUE}\\\text{TO DELIVERY DELAY}\end{array}} + \frac{\text{BACKLOG} - \text{DESIRED BACKLOG}}{\text{5 MONTHS}} \qquad (2)$$

The estimate of the fraction of demand realized due to delivery delay is shown in Figure 4. The solid line is the perfect estimate of how delivery
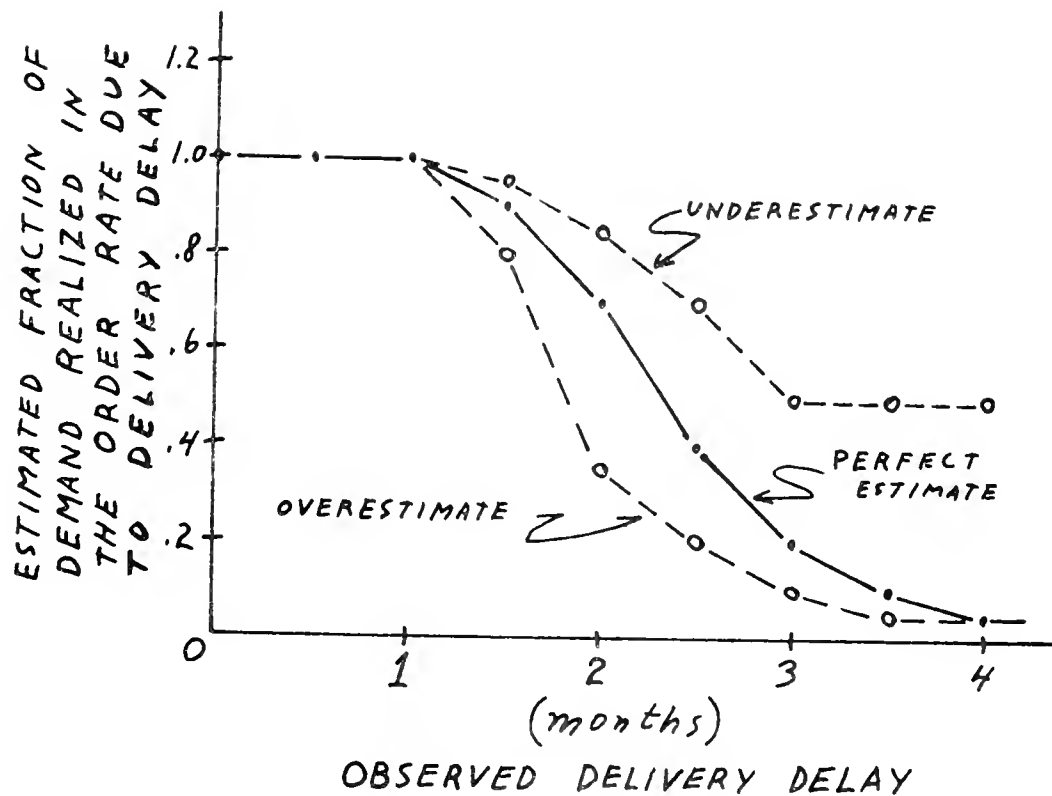
FIGURE 4. Estimated Fraction of Demand Realized
in Order Rate Due to Delivery Delay

delay affects the order rate.

The difference between the growth of resource for the typical policy (heavy dashed line Figure 5) and the growth of resources controlled by the new policy (heavy solid line Figure 5) is significant. The improved behvior is due to the use of competitive variable information. Except for the estimate of demand, the resource management in Figure 5 is identical to the typical policy of Figure 3, that is, the acquisition of resources takes twelve months, the desired resource policy is represented by the solid line in Figure 2, and the firm attempts to bring backlog to one month of orders in five months. For the simulation run in Figure 5, it is assumed that management has estimated perfectly the fraction of demand realized due to the delivery delay. The use of the delivery delay information improves the exploitation of demand because it boosts the desired resources and thus the growth in resources when demand is growing rapidly. Yet when resources catch up as growth in demand slackens and overcapacity is threatened, the delivery delay improves and slows the growth of resources. No excess resources appear.

In addition to using the competitive variable to estimate demand, this paper recommends a more aggressive resource acquisition than the policy of Figure 5. The recommended policy for desired resources is the dashed line in Figure 2. It increases resources 25% instead of 10% when the desired shipment rates equal production capacity.

The recommended policy also attempts to bring backlog to its desired value in three instead of five months. With the more aggressive resource acquisition, estimates of demand from the competitive variable,
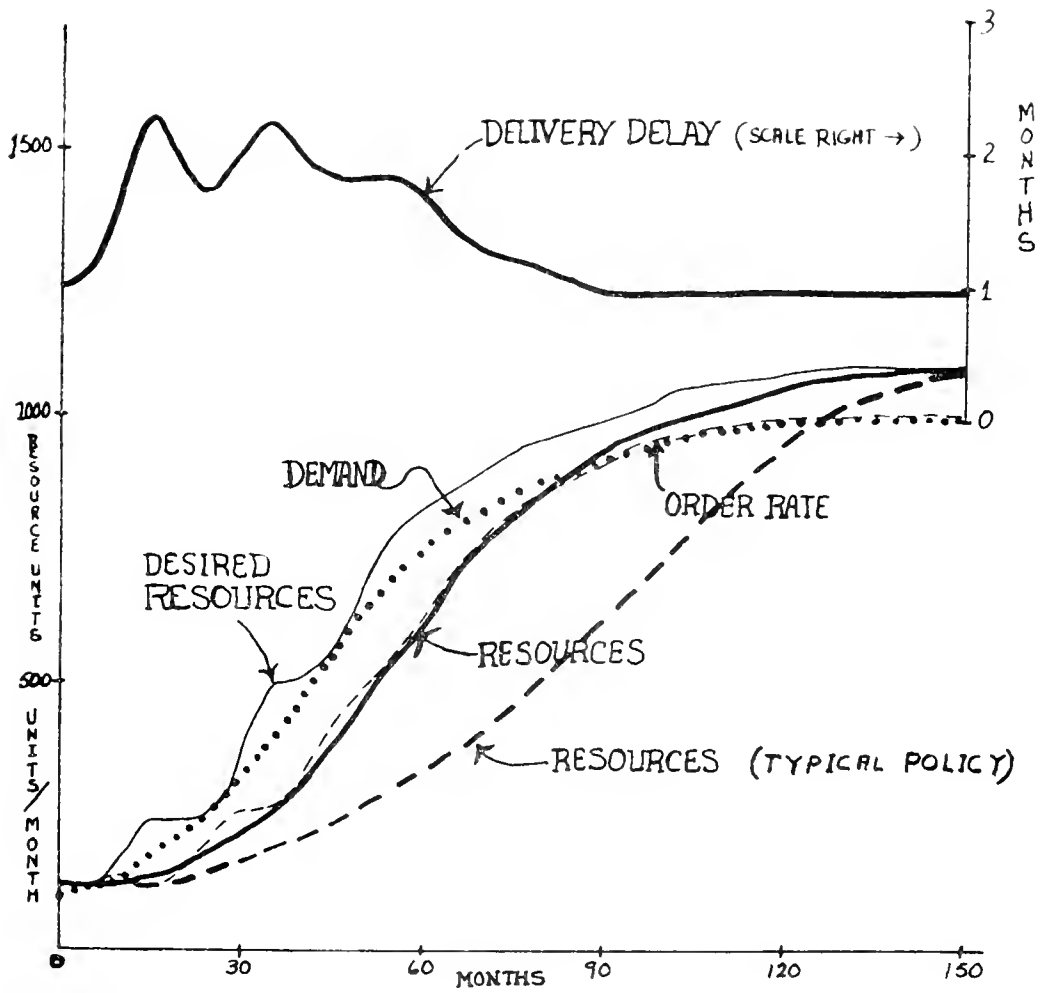
FIGURE 5. Estimating Demand Using Delivery Delay
Information but with Typical Aggressive-
ness of Resource Control; Twelve-Month
Resource Acquisition Delay

and a shorter, eight months, time to acquire resources, demand is exploited better than in Figure 5 and no unwanted resources develop. However, when demand is estimated from competitive variable information, behavior is changed relatively little by the changes in the aggressiveness of resource control. This insensitivity to changes in the decision parameters of the control policy is a mark of a well-designed policy.

ASSESSMENT OF RISK

It is naive and useless to say that a perfect estimate of demand, which happens to be based upon knowledge of how a competitive variable affects the order rate, can improve the exploitation of resources. Obviously a perfect estimate of demand improves behavior. To give substance to the recommended policy one must show either 1) that it is possible to estimate accurately the effect of the competitive variable upon the order rate or 2) that the recommended policy creates good behavior which is insensitive to the kinds of error found when using intuition and experience to estimate the effect of the competitive variable upon the order rate. Here we demonstrate the latter.

Most managers would reject the recommended policy because it appears too risky. They would fear that an overestimate of the impact of the competitive variable upon the order rate would lead to an overestimate of demand and excess resources. These fears are borne out by a simulation run which coupled together aggressive resource acquisition, an over-

estimate of demand due to a two-to-one overestimate of the impact of

the competitive variable upon the order rate (lower dashed curve in

Figure 4) and a twelve-month delay in acquiring resources. Resources

exceeded demand by 71.5% at the end of the run. However, the over-

capacity came when desired resources were 299% above the current pro-

duction rate. To reduce the risk of overcapacity and the sensitivity

of behavior to errors in estimates of demand, resources can be acquired

conservatively with the concommitant risk of failing to exploit a rapidly

growing demand (Figure 3) or the growth rate of resources can be limited.

This growth limit can be determined either from an estimate of the maxi-

mum rate of growth in demand or an estimate of the maximum rate at which

the firm will grow efficiently.

The behavior of the recommended policy including the growth limit

of resources is shown in Figure 6. The good exploitation of demand, no

excess capacity, and the similarity of behavior to Figure 5, shows that

when a growth limit is included, the recommended policy is insensitive

to overestimates of the impact of the competitive variable upon the

order rate. The recommended policy with the growth limit performs well

even though demand is overestimated by nearly a factor of two (the thin

solid line at Month 20 and Month 40 in Figure 6) because of the self-

correcting estimate of demand. This self-correcting characteristic is

the cause of the insensitivity to error in estimates of the relations-

ship between the competitive variable and order rate. The self-correcting

behavior is due to the feedback loop which connects resource control,

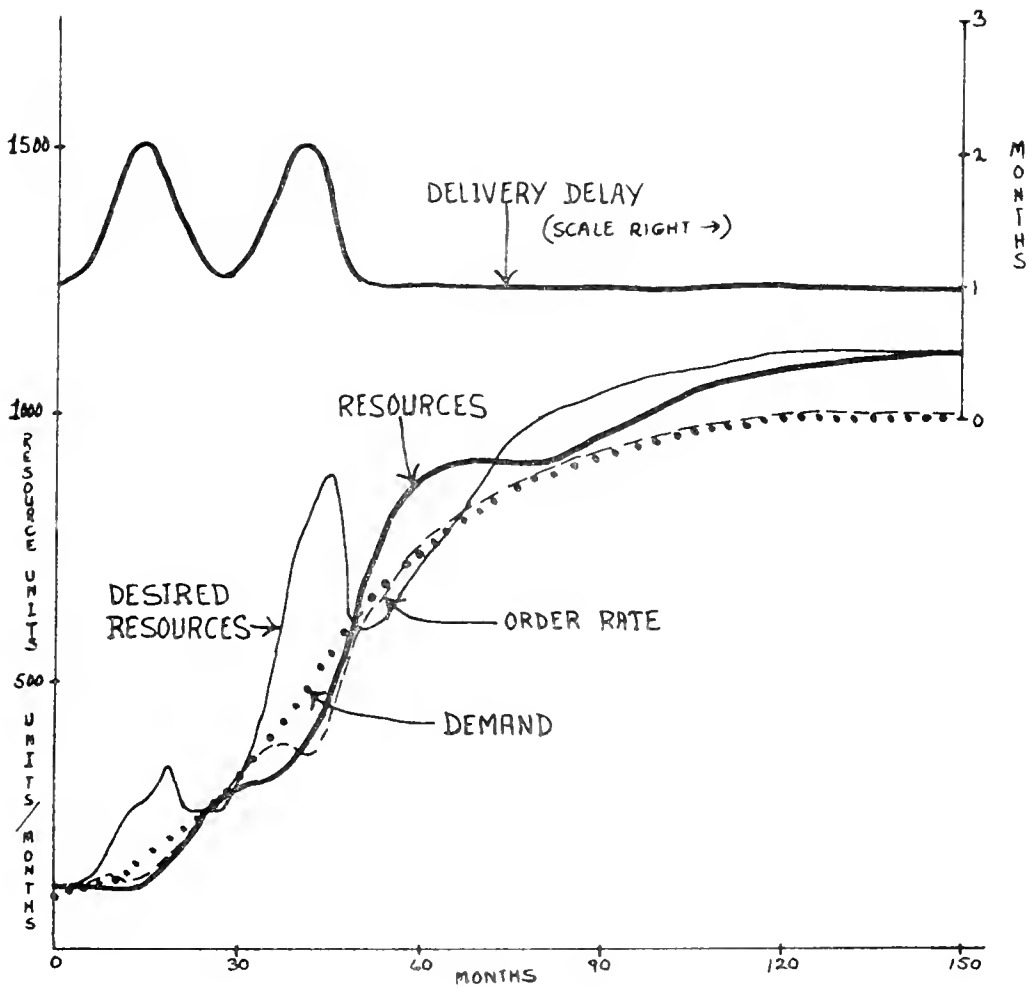resources, and the competitive variable and which is created by using

FIGURE 6. Recommended Resource Management Policy with Overestimates of Delivery Delay Effect on Order Rate

competitive variable information to estimate demand for the control of resources. From Figure 6 we can see the self-correcting mechanism in operation. When demand outstrips resources, delivery delay builds up. When delivery delay rises to two months, demand is overestimated by a factor ot two. The overestimate of demand produces a heavy ordering of resources but not so much to guarantee overcapacity. The rapidly increasing resources eventually correct the estimates of demand by reducing the delivery delay to a normal value where the estimates of the effect of delivery delay upon the order rate are accurate (Figure 4).

The recommended policy gives good behavior for another reason. Since resources are ordered aggressively, the only time that the delivery delay can build up is when demand is growing very rapidly. Consequently the overestimates of demand and overbuilding of resources are quickly absorbed by the rising demand. The policy produces excess resources only when a rapidly growing demand will absorb any mistakes.

The recommended policy is insensitive to underestimates of the effect of the competitive variable upon the order rate, top dashed line in Figure 4 ([13] pp. 105-112). The behavior of the recommended policy is also insensitive to delays of acquiring resources which range from four to twelve months ([13] pp. 115-116), and to random error, bias, and delay in the information of the competitive variable.

Different Shapes of Demand

Well-designed resource management must also give good behavior for

a wide variety of shapes of demand. Simulations show that the recommended policy effectively exploits a slowly growing demand without generating excess resources. A much more demanding test of the policy is its response to demand that rises very rapidly for a short time and then levels out suddenly. The rapid growth in demand forces management to increase resources sharply or poor demand exploitation results. However, the quick leveling of demand allows little correction of error, so any tendency of a resource control policy to acquire excess resources is spotlighted. In Figure 7 the resource control policies contend with demand which doubles each year for two years, grows by 25% in one year, and then levels out. Producing the effective exploitation of demand and only 1%
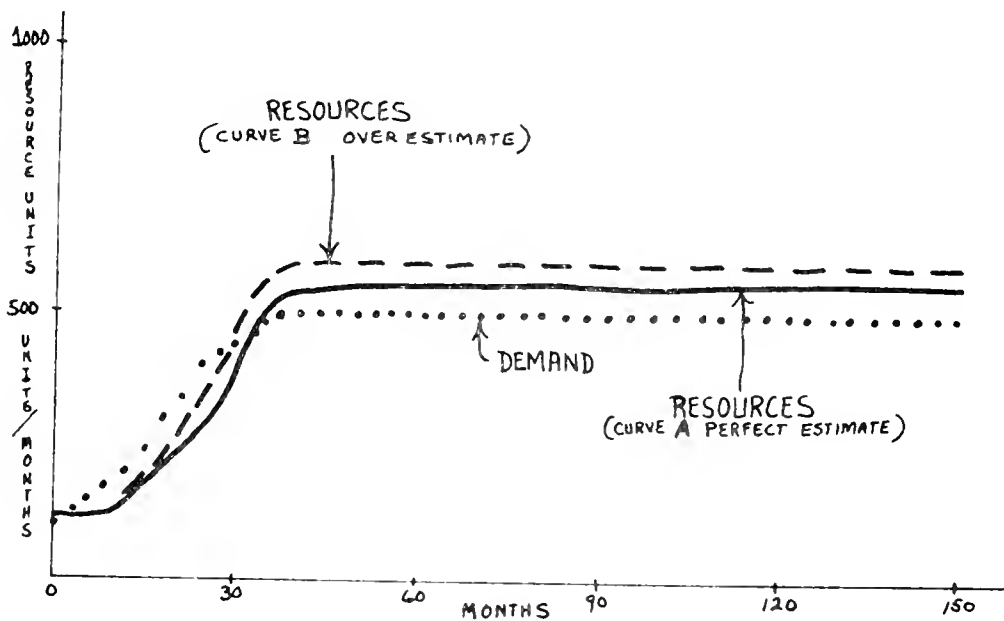

FIGURE 7. Recommended Resource Management Policy Facing Sharply Rising then Suddenly Leveling Demand

unwanted capacity, curve A, is the recommended policy, i.e., it is
aggressive, uses delivery delay information, estimates perfectly the
impact of delivery delay upon the order rate, limits the growth rate
of resources to 120% per year, and acquires resources in eight months.
Resource curve B is produced by the recommended policy except that the
effect of delivery delay upon the order rate has been overestimated.
One would expect excess resources, but the resource growth limit keeps
the resources from overshooting and resources are added quickly enough
to keep delivery delay low and in regions where error in estimates of
demand is small. Excess resources of 9% are generated which is insigni-
ficant for this extreme test.

Most markets do not rise and level off smoothly. Normally demand
has ups and downs during growth. Ideally, a resource control policy
ought to be able to exploit the long-term growth in demand and ignore
the temporary, random surges. But with random fluctuations of demand,
the resource control policy faces a dilemma. The policy which exploits
rapid growth well responds immediately and strongly to an upsurge in
demand before it is clear whether the upsurge in demand is the start of
a permanent increase or a temporary random spurt. If the surge is per-
manent, the aggressive policy has successfully exploited the market.
If the surge is temporary, excess resources decrease financial performance.

This dilemma is illustrated in Figure 8. Demand grows ten-fold in
ten years but with random fluctuations. The resulting demand curve is
volatile. Beginning at Month 42, it grows 150% in twelve months, and

then declines 40% in the following twelve months. When demand levels out, the fluctuations vary ±25%, about an average of 1000 units/month with a period of about three years from peak to peak.

The dashed line in Figure 8 shows the behavior of resources generated by the recommended policy with a perfect estimate of the impact of delivery delay upon the order rate and purchasing resources of which it cannot dispose. The result is resources 38% greater than average demand which is not much greater than the 28% excess of the most conservative policy, now shown, while the exploitation of demand is much better. In a simulation not shown, the recommended policy with overestimates of the impact of delivery delay upon the order rate gave very similar results.

The solid line in Figure 8 shows excellent behavior of resources resulting from the recommended policy and a perfect estimate of the impact of delivery delay upon the order rate but purchasing flexible resources, i.e., resources that can be reduced. Excess resources are avoided and yet the firm exploits demand effectively. The greatest use of the flexibility occurs when resources are reduced 24% in two years between Month 96 and Month 120. Ten percent changes in resources over six to nine months are more common. These changes are not large and could be realized if a fraction of resources were flexible. Assuming that management is willing to have fixed resources greater than needed during temporary troughs in demand, having 20% of total resources flexible would seem ample. In a production process, overtime, subcontracting, double shifts, and inventory should yield at least 20% flexible resources.
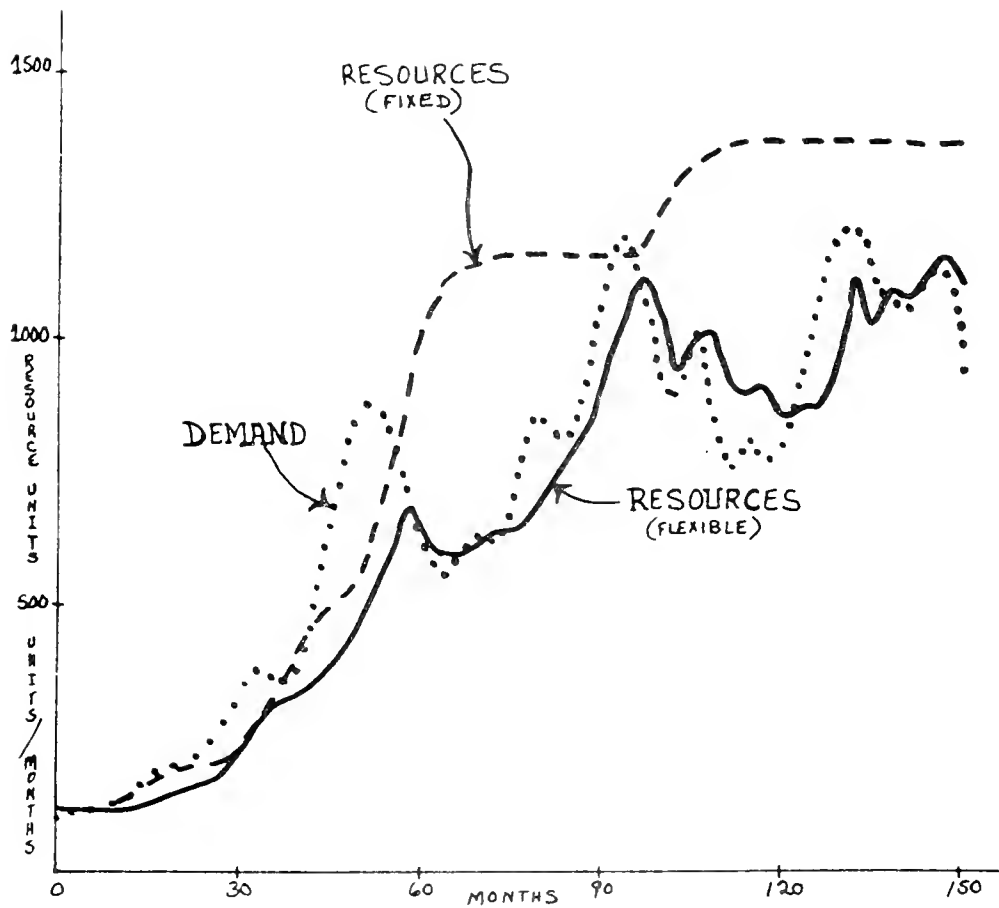
FIGURE 8. The Recommended Resource Management Policy with Fixed and Flexible Resources in a Fluctuating Market

IMPLEMENTATION

In order to exploit a growing market with low risk of excess capacity, this paper recommends that resource management

1.   Uses information about the competitive variables

2.   Acquires resources aggressively

3.   Determines a maximum growth rate of resources

4.   Acquires resources quickly

5.   Insures that a fraction of resources are flexible.

Implementation requires an estimate of the relationship between the competitive variable and the order rate (Figure 4). There is not enough data to use statistical analysis of time series to estimate the relationship. The author believes that interviews to find customers' attitudes about the firm's performance, experience in the industry, and intuition are usually adequate to estimate within tolerable error limits the relationship between competitive variables and the order rate. The most critical point to estimate is when the competitive variable is at a normal value and thus the order rate equals demand. From experience, intuition, and interviews one ought to estimate this point fairly accurately. Otherwise relatively large errors are tolerable. The reason managment frequently fails to use such information is the belief that errors in information automatically create risk. However, the main point of this paper is that managment can use competitive variable information in resource control at low risk because of the self-correcting, feedback relationship between the recommended resource management policy and the competi-

tive variable. This conclusion is supported by the work of Schrage[11] who reports that awareness of customers' attitudes about the performance of their company is one characteristic of successful technical entrepreneurs. Wright's work[16] also supports the conclusion. In his study the effect of speed of service on the orders for the Scannell Trucking Company was estimated by intuition, but the implementation of new policies was very successful and confirmed the predictions of the simulation model.

Implementation poses three other problems. First, every firm manages several resources which affect several competitive variables. These resources are different. They have different operating and capital costs, it takes different amounts of time to acquire them, and it takes different amounts of time for changes in a resource to affect the market. As has been shown [3,5,6] if the balance among different resources is not properly maintained, growth will be retarded and profits will be reduced. Second, market dynamics can be different than assumed above. For example, customers might order ahead when a competitive variable deteriorates in anticipation of further deterioration instead of reducing orders as assumed above. Capital goods' and durable goods' markets also have different dynamics. Customer needs are satisfied by an inventory of goods. When needs are growing, orders rise to high levels, but as the customers' inventory is filled, the order rate falls as customers order only for replacement. The information flow, resource control policies, and resource packages which are used to exploit markets with different dynamics

need to be altered from those recommended above. Third, the policies that control the balance between flexible and the fixed resources need to be carefully designed so that the organization does not raise costs by using expensive, flexible resources to bail itself out of crises that would have been avoided by better management of fixed resources.

The study of the Scannell Trucking Company[16] illustrates how a company can implement the recommended policy. By building a computer simulation model of the interaction of the resources and the market, Scannell dealt with the errors of an intuitive estimate of the relationships of service and the order rate, different market dynamics, three resources, and in its case two classes of demand. Analysis of this model resulted in new policies. Contrary to the industry's tradition, empty trucks were quickly sent to terminals where loads piled up. A three-month delay in purchasing new trucks was found to retard growth and the purchasing delay was reduced to one week. Salesmen were found to be useless for short-term control of the order rate. When the capacity of a terminal began to constrain growth, the model showed the economics of alternative decisions on fleet size, customer service, and overtime for the loading dock workers. Analysis with the model pointed out the economics of balancing the mix of freight that needed one-day delivery and freight with a five-day delivery requirement. The model showed and subsequent analysis of data confirmed that current policies were creating six-month cycles in the order rate. As mentioned above testing showed the new policies to be insensitive to greatly different assumptions about the effect of speed of service upon the order rate. Implementation in-

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creased growth rate and profits. In the Scannell case the initial model building, analysis of current policies, and design of new policies took a few months of part-time effort by two or three people.

Implementation Guidance

Other firms can construct models to be used for designing information flows and resource control policies which will improve performance. Analysts will find guidance for their work in the System Dynamics literature. Discussion of growth processes [3,4,5,6,13,14,16] will aid in problem identification, model building, and design of strategy. More detailed analyses of how information systems and control policies establish dynamic behavior contained in discussions of production-distribution systems [1,2,9,10,12,15] will pinpoint issues to be considered and will guide the design of the specific information flows and decision rules.

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Date Due